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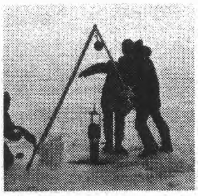
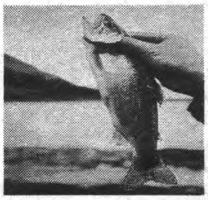
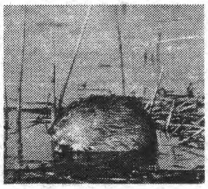




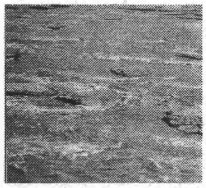





NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 135

ECOTOXICOLOGY OF SUSPENDED AND BOTTOM SEDIMENTS,

ATHABASCA, SMOKY AND PEACE RIVERS, JUNE, 1995



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by

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National Water Research Institute, Environment Canada

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F. J. Wrona
(Dr. Fred J. Wrona, Science Director)

14 May 96
(Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P.A. Larkin
(Dr. P. A. Larkin, Ph.D., Chair)

24 May/96
(Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington
(Lucille Partington, Co-chair)

May 29/96
(Date)

Robert McLeod.
(Robert McLeod, Co-chair)

May 21/96
(Date)

ECOTOXICOLOGY OF SUSPENDED AND BOTTOM SEDIMENTS, ATHABASCA, SMOKY AND PEACE RIVERS, JUNE, 1995

STUDY PERSPECTIVE

Organic contaminants entering aquatic ecosystems can become associated with organic and inorganic materials contained in the water column. Under varying circumstances these materials will settle out. The presence and persistence of contaminants in these sediment depositional zones may constitute a source of toxicity to organisms which live on or near the substrate. Toxicity from contaminants may have direct as well as indirect effects on other organisms which use them as food. Benthic invertebrates are considered good overall indicators of contaminants in sediments because, as a group, they are in direct contact with sediment solids. A Northern River Basins Study (NRBS) project undertaken in 1993 found that depositional sediments from two sites downstream of Hinton and suspended solids collected from near Ft. McMurray were toxic to oligochaete worm reproduction. However, information on contaminant levels at these sites was insufficient to explain the observed toxicity.

The objectives of this project were to (1) re-examine sediment toxicity at sites sampled previously on the Athabasca River, including the oil sands area, and (2) conduct toxicity testing on a number of additional collection sites on the Athabasca, Smoky and Peace rivers. Suspended and bottom sediment samples were tested using four species of freshwater benthic invertebrates in chronic exposure studies. The endpoints that were measured included survival, growth (amphipod, chironomid and mayfly) and reproduction (oligochaete worm). The test results were compared with standard reference sediment samples from Long Point Marsh, Ontario, for biological quality assurance.

Related Study Questions

1a) *How has the aquatic ecosystem, including fish and/or other aquatic organisms, been affected by exposure to organochlorines or other toxic compounds?*

4a) *What are the contents and nature of the contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?*

13b) *What are the cumulative effects of man-made discharges on the water and aquatic environment?*

14) *What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure that all stakeholders have the opportunity for input.*

Growth and survival of the chironomid was not affected by exposure to the test sediments. However, the other three invertebrates showed reduced survival, growth and/or reproduction when exposed to bottom sediments from some sites. Specifically, effects were recorded for the following sites: Athabasca River - upstream of Hinton, downstream of Whitecourt, downstream of Alberta-Pacific and near the Athabasca delta; Smoky River - upstream of the mouth of the Wapiti River; Peace River - upstream of the mouth of the Smoky River. The observed effects of exposure to bottom sediments at these sites may have been due to the combined effects of chemical contaminants (elevated levels of copper and zinc) and physical characteristics (high sand content). Another possible explanation is that the observed effects were due to compounds not measured in this study. Only the oligochaete worm was exposed to suspended sediments and, although the results were more variable than for bottom sediments, there were few toxic effects on reproduction.

Results from this project indicate that there are localized areas of contamination in suspended and bottom sediments, leading to toxicity responses in bottom-dwelling invertebrates. This information will be incorporated into a model to determine the environmental health for specific reaches of these rivers. Results from this research will be used to prepare a report on cumulative impacts as well as support the development of biomonitoring guidelines for these northern rivers.

REPORT SUMMARY

In June 1995, samples of whole sediment (five replicates per site) and suspended sediment (one sample per site) were collected from various locations in the Athabasca, Smoky and Peace Rivers, Alberta. Four species of benthic invertebrates, the chironomid *Chironomus riparius*, the amphipod *Hyalella azteca*, the mayfly *Hexagenia* spp. and the oligochaete worm *Tubifex tubifex* were exposed to these samples in 10 to 28 day chronic toxicity tests. The endpoints measured were survival and growth of *C. riparius*, *H. azteca*, and *Hexagenia* spp. and survival and reproduction of *T. tubifex*. With the exception of the chironomid, some or all of the other species had reduced survival, growth and/or reproductive output when exposed to whole sediments collected from sites AR1, AR5, AR8 and AR 9 in the Athabasca River. These effects were attributed to either the presence of elevated levels of metals (Cu and Ni) at some of the sites and/or the high sand content. Levels of Cu and Ni were slightly above the Lowest Effects Level (LEL) for sediments in Ontario established as a guideline for toxicity to benthic invertebrates. In the case the burrowing mayfly, *Hexagenia* spp., low survival could be attributed to a high percentage of sand at sites AR1 and AR8. This species does not tolerate sandy sediments due to its inability to construct burrows in this type of sediment. No major toxic responses were observed for *C. riparius* at any sites. Adult worms of *T. tubifex* exposed to suspended sediments collected by centrifugation of water from the various rivers had reduced reproduction at only two sites, AR5ss and AR09ss, and the results from duplicate samples were variable. Sites located in the oil sands area of the Athabasca River (AR6-suspended solids, and AR7) did not appear to have any major toxic effects on most test animals.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The use of benthic invertebrates as test organisms in chronic whole sediment toxicity tests is well documented (Burton *et al.* 1992; ASTM 1995; USEPA 1994). Benthic invertebrates represent a wide range of life histories and feedings habits, and therefore can be effective monitors of contamination of sediments by their intimate contact with the benthos. For example, the amphipod *Hyalella azteca* and the chironomid *Chironomus riparius* are grazers on the surface sediments while the oligochaete worm, *Tubifex tubifex*, is a burrower and ingests sediment particles. The various modes of feeding and burrowing by these organisms offer different means of exposure and biological insult ranging from ingestion of chemicals bound to surface particulates to passive diffusion of contaminants through the integument during close contact with intersitital water.

Some animals living in and around areas of the Athabasca, Smoky, and Peace Rivers (Alberta) have exhibited toxic responses to water and sediment at localities near and within the oil sands (MacInnis *et al.* 1992; Brownlee *et al.* 1993). Other bioassays conducted using bottom sediments from specific sites in the Athabasca River (Day and Reynoldson 1995) showed no significant toxic effects on invertebrates, with the exception of an effect on reproduction by *T. tubifex* at a number of sites. In addition, a sample of suspended solids collected from the oil sands area in 1994 produced a high level of acute toxicity to *Tubifex tubifex*. The objectives of the present study were 1) to collect bottom sediments from eight locations within the Athabasca River, and four locations within the Smoky and Peace Rivers; 2) to collect suspended solids from ten locations within the Athabasca River, and six locations in the Smoky and Peace Rivers; 3) to assess the toxicity of these sediment samples to four species of benthic invertebrates (the chironomid *Chironomus riparius*, the mayfly *Hexagenia* spp. (*H. limbata* and *H. rigida*), the amphipod *Hyalella azteca*, the oligochaete worm *Tubifex tubifex*) in chronic laboratory toxicity tests; 4) to characterize the sediments for their physical and chemical variables; 5) to relate potential toxicity to physical and chemical variables of the sediments.

2.0 METHODS

Sediments were collected from the Athabasca, Peace and Smoky Rivers (Alberta) at 12 locations in June 1995, for chronic toxicity testing using the four species of benthic invertebrates described above. At each station on a river, five replicate samples (≈ 500 mL) were taken with an Eckman dredge, placed individually in plastic bags of food container quality and stored on ice in a cooler until shipment to NWRI, Burlington, Ontario. In addition to the whole sediments, 16 sites (one sample each) from the same three rivers were sampled for suspended sediments for testing using the oligochaete worm, *T. tubifex* (Tables 1a, 1b., Fig. 1). An Alfa-Laval centrifuge was used for the collection of suspended solid samples; the centrifuge was operated for a time period to allow for the collection of a 500 mL sample. All samples were bagged, placed on ice in coolers and shipped immediately to NWRI, Burlington, Ont., where they were placed in a 4°C refrigerator until use in bioassays.

2.1 Sieving Procedures

Sediment from each replicate was gradually mixed with 2 L of culture water (dechlorinated city of Burlington tap water), and passed through a 250 μm sieve. After a 24 h settling period, the overlying water (test water) was separated from the sediment (test sediment), and both parts were stored until testing. Prior to sieving, a sediment sample of approximately 250 mL was removed from each replicate for physical and chemical analysis. Endemic species have been shown to complicate the interpretation of results from whole sediments (Reynoldson *et al* 1994) which necessitate sieving.

2.2 Physical and Chemical Analysis

Particle size determination of sediment was performed on lypholysized samples at the National Water Research Institute, Burlington, following the procedure outlined by Duncan and LaHaie (1979). Large particles (>0.88 mm) were removed from the sediment sample prior to analysis. The sediment was then placed in sodium metaphosphate solution, mixed for fifteen minutes and wet-sieved through a 0.063μm mesh. The material remaining on the sieve was dried, added to the large particles previously removed and the total was recorded as percent sand and gravel. The remaining suspension was analyzed using a sedigraph analyzer and results were expressed as percent silt and clay.

Chemical analyses were carried out by Seprotech Laboratories, Ottawa, Ontario, Canada. Analyses conducted were total organic carbon (TOC), total nitrogen, total phosphorous, and loss on ignition (LOI). Concentrations of metals were determined by acid digestion followed by ICP-AES analysis (Multi-channel Jarrell-ASH AtomComp 1100) using the methods of McLaren (1981).

2.3 Sediment Toxicity Testing Procedures

All tests were conducted in conjunction with reference sediment samples for biological quality assurance collected from a wetland area near Long Point Marsh, Lake Erie, Ontario. Culturing methods for *C. riparius* and *T. tubifex* are outlined in detail in Reynoldson *et al.* (1991), Day *et al.* (1994), and Reynoldson *et al.* (1995). Culturing of *H. azteca* is described by Borgmann *et al.* (1989). Eggs of *Hexagenia* spp. were collected in late June and July, 1995, using the methods of Hanes and Ciborowski (1992). Eggs were placed in aquaria with sieved long point sediment and culture water, and fed *Hexagenia* diet (3 parts cerophyll, 3 parts yeast, 4 parts nutrafin, in D.I water), twice weekly.

Bioassays conducted with *Chironomus* and *Hyalella* used a 50 mL:150 mL sediment:water (v:v) ratio in a 250 mL glass beaker and were replicted five times. Bioassays with the mayfly were conducted using 1 L glass jars containing 100 mL of test sediment and 800 mL of overlying water, respectively. Bioassays with the oligochaete worm used a 100 mL:100 mL sediment:water (v:v) ratio per replicate. All bioassay containers were allowed to settle for 24 h prior to addition of animals to the test containers. *Chironomus* and *Hyalella* tests contained 15 animals per replicate, *Hexagenia* tests used 10 animals per replicate, and worm tests used 4 animals per replicate. *C. riparius* was in the first instar and approximately 2-3 d post-oviposition at test initiation; *H.azteca* juveniles were 7 to 10 d of age; *Hexagenia* nymphs were approximately 6 weeks of age, or, 5 to 10 mg wet weight each, and *T. tubifex* were sexually mature and 6 to 8 weeks of age when added to the beakers.

During the test period, feeding was carried out twice weekly for *Chironomus* and *Hyalella*, and once a week for *Hexagenia*. *C. riparius* and *H. azteca* received 8 mg dry weight of Nutrafin^R administered as a water slurry to each beaker and *Hexagenia* received 50 mg of *Hexagenia* diet per feeding. At the onset of the *T. tubifex* test, 80 mg of Nutrafin^R was mixed into the sediments and no other feeding was carried out during the exposures.

All test were conducted at 23.0 °C ± 1°C, with a photoperiod of 16 h light: 8 h dark. All tests were aerated continuously. Parameter measurements (pH, D.O, temperature, conductivity) were taken at the onset, midway, and at the end of each test, as well as ammonia upon completion. Tests were terminated after 10 d for *C. riparius*, 21 d for *Hexagenia*, and 28 d for *Hyalella* and *Tubifex*.

At the end of the exposure period, *Hexagenia*, *Chironomus*, and *Hyalella* were separated from test sediment by sieving lightly through a 250 μm mesh. *Tubifex* were sieved through a 500 μm mesh, then through a 250 μm mesh, to separate adults and cocoons from young. End points for *Hyalella*, *Hexagenia*, and *Chironomus* were survival and increase in weight (mg dry weight/.ind). The end point for *Tubifex* was survival, number of empty and full cocoons, and number of young per individual. Initial weights of *Hyalella* and *Chironomus* were considered to be zero, and initial weights of *Hexagenia* was determined from the dry weights of test animals extrapolated from wet weights measured just prior to animal addition (formula used: mean wet weight + 1.15/7.35 derived from unpublished data for the past five years in laboratory).

2.4 Statistical Analysis

All data for each species and each response were tested for normality and homogeneity of variance prior to analysis using one way analysis of variance (ANOVA) for comparison of means among sites. Data for survival were transformed using the arcsin transformation before statistical comparisons were conducted; however, data are presented as percent survival in all tables and figures. Parametric or non-parametric analyses were used depending on the outcome of normality and variance equality tests. If data passed the tests for normality and equal variance, comparison of means was conducted using

Student-Newman-Keuls test for parametric analysis. If data failed the test for normality, the Kruskal-Wallis One-Way Analysis of Variance on Ranks for non-parametric analysis was used to determine among-site differences. For the Athabasca River, all sites within the river were compared to each other and to the negative control sediment (Long Point) run concurrently with all sets of bioassay. Results from the Smoky and the Peace Rivers were compared to each other as well as to the negative control. All statistical analyses were performed using the software package, Sigmastat™ (v. 3.0 Jandel, California) and significance is at a level of $p \leq 0.05$.

Responses in sediments were also compared to established acceptability levels of 70 % survival for *C. riparius*, 80 % survival for *H. azteca* and 80 % survival for *Hexagenia* published in USEPA (1994) and ASTM (1995). In addition, growth and production of young for each respective species were compared to levels obtained by Day *et al.* (1995) from a range of clean, reference sediments (258 stations) in the Great Lakes with a variety of grain sizes and organic carbon. The criteria for growth and reproduction from this data set were set at the 5th percentile on the normal distribution curve for the range in responses for each endpoint and species in 258 reference sites and are as follows; *C. riparius*- % survival ≥ 68.0, growth ≥ 0.22 mg dry weight/ind.; *H. azteca*- % survival ≥ 74.7, growth ≥ 0.22 mg dry weight/ind.; *Hexagenia* spp.- % survival ≥ 84.0, growth mg dry weight/ind.≥ 0.58; *T. tubifex*- ≥ 8 cocoons\adult worm, ≥ 9 young\adult worm. These values were used simply as a reference point for the lower end of the survival, growth and reproductive scale for benthic invertebrates exposed to clean sediments.

3.0 RESULTS

Physical and chemical data for all samples of sediment and suspended sediment are shown in Tables 2 to 5. The Province of Ontario has set a Lowest Observable Effects Level (LEL) and a Severe Effects Level (SEL) for benthic invertebrates exposed to contaminated sediments for metals and other chemical components (Persaud *et al.* 1992). These values are included in Tables 4 and 5 and are used for comparative purposes as similar LEL and SEL have not been developed for Alberta situations. Concentrations of contaminants in the sediments collected in this study were generally lower in values than the LEL set for Ontario although occasionally higher levels (above the LEL but below the SEL) for copper and nickel were recorded for several sites. Levels of total phosphorus (TP), total Keljdahl nitrogen (TKN) and % total organic carbon (TOC) were also higher than the LEL for several sediments and suspended sediments collected by centrifugation.

Results from the negative control sediment, Long Point (LP) run concurrently with all bioassays met or exceeded the acceptablity criteria set by ASTM (1995) and USEPA (1994) for a valid test. These levels have been set at 70% survival for *C. riparius* and 80% survival for *H. azteca* and *Hexagenia* spp. and are termed acceptability criteria in these documents. There have been no similar levels set for increases in biomass (growth) during exposure or reproductive output.

Results from the bioassays are presented in Figures 2 to 8. Results for each river system are compared statistically within a watershed. Therefore, comparisons are confined to sites within the Athabasca River (AR) or within the Smoky and Peace Rivers (SR and PR) as there was only one site sampled in the Smoky River. Statistical interpretation on the figures is represented by using lower case lettering for comparisons of Athabasca River sites, and, upper case lettering for comparisons among Smoky and Peace River sites. The samples from the reference site, Long Point, were run concurrently with every 2-7 bioassay samples. Sites with the same letter are not statistically different from each other at the 0.05 level. Where applicable, the lower end of the normal spectrum of responses (2 standard deviations (S.D.) from the mean) for the same organisms from a large number of clean sediments collected from near-shore areas of the Great Lakes is presented on each figure as a dotted line. This is to serve only as a non-statistical relative comparison between results in the current study and results from "clean" sediments for growth and reproductive responses which have no set levels of acceptability documented in the literature.

3.1 *Chironomus riparius*

Chironomids exposed to sediments collected from the Athabasca, Smoky and Peace Rivers had high survivorship (80-100%) (Figure 2 and Appendix A). The criterium for an acceptable level of survival in clean or control sediment is 70% (ASTM 1995) and all samples exceeded this level. Comparison of means for increase in biomass (mg dry weight\individual) for *C. riparius* exposed to sediments collected on the Athabasca River indicated less growth at sites AR7, AR8 and AR9 than at other sites in the Athabasca River. However, the growth of these organisms was above the lower 5th percentile for growth in 258 reference sediments in the Laurentian Great Lakes and similar to growth exhibited in the reference sediment collected from Long Point. Similarly, growth of animals at sites in the Smoky and Peace Rivers was within the range found in the reference sediment.

3.2 *Hyalella azteca*

Several statistical differences were observed for survival and growth of *H. azteca* at a number of Athabasca River sites. Percent survival was particularly low at AR1, AR5 and AR8 (i.e., lower than the level for reference sediments as well as the acceptability criterium of 80% survival set for the test by ASTM (1995) (Figure 3 and Appendix B). Survival of animals in the Smoky and Peace River sediments was high (>80%) (Figure 3 and Appendix B). Growth of *H. azteca* was also low at sites AR1, AR3 and AR8 but was particularly reduced at site AR1. This reduction in biomass was also below the lower end of the reference sediment scale set for *H. azteca* in clean sediments. Growth of *H. azteca* in sediments collected from the Smoky and Peace Rivers was similar at all sites (Figure 3 and Appendix B) and above the level set for reference sediments.

3.3 *Hexagenia* spp.

Survival of the burrowing mayfly was very high at most sites with the exception of sites AR1 and AR8 for the Athabasca River where percent survival was significantly reduced below 20% (Figure 4 and Appendix C). Growth was also reduced at these two river sites and was negative at AR8 (animals lost weight over the period of exposure). Site SR1 was significantly lower than the Peace River sites (Figure 4 and Appendix C) as well as below the level considered acceptable for clean Great Lakes sediment. Animals exposed to the QA reference sediment from Long Point which was highly organic exhibited higher levels of growth.

3.4 *Tubifex tubifex*

3.4.1 Whole Sediment

Percent survival of adult tubificid worms was high for all sites in the Athabasca, Smoky and Peace Rivers (i.e., 90-100%; Figure 5 and Appendix D). The percentage of empty cocoons per adult worm was reduced at site AR9 compared to all other sites (Figure 6 and Appendex D). This increase in the number of full cocoons may represent a delay in the hatching of young worms and a possible effect on embryogenesis. Mean cocoon production per adult worm was not reduced at this site but was statistically lower at sites AR1 and AR8 than at the other sites as well as the QA sediment from Long Point. This reduction in the number of cocoons per adult worm was also lower than the number expected at clean reference sites (dotted line). The mean number of offspring/adult worm was also lower at sites AR1, AR8 and AR9 in the Athabasca River and at site SR1 in the Smoky River as well as that determined for the QA reference site. However, this lower reproductive effort for the Athabasca River is within the range recorded for this species in a variety of sediments from the Great Lakes.

3.4.2 Suspended sediments

Results from bioassays with worms exposed to suspended sediments (Figures 7, 8 and Appendix E) were more variable than with whole sediments. Few statistical differences among sites could be documented due to this variability. Mean survival of adult worms was low at site AR5ss, AR6.1ss, and AR9ss but this reduction in survival was not statistically significant. Survival at the duplicate site AR6.2ss was 100%. Adult worms exposed to suspended sediments from all sites had a higher number of offspring per adult compared to the lower 5th percentile recorded for reference sediments; however, reproductive effort at AR5ss, AR6.1ss, and AR9ss was lower than at the other sites and the QA reference sediment from Long Point. Although not statistically significant, sites AR5ss and AR6.1ss had a lower reproductive effort relative to other locations in the Athabasca River, and, in the case of cocoons production, were lower than the reference level.

4.0 DISCUSSION

The results from this study indicate that exposure of the benthic invertebrates, *Hyalella azteca*, *Hexagenia* spp. and *Tubifex tubifex* to whole sediments collected from some locations in the Athabasca, Peace and Smoky Rivers reduced survival, growth and\or reproduction, at some sites compared to results from clean sediments collected in other areas of Canada. Effects were noted specifically at sites AR1, AR5, AR8, AR9, SR1, and PR2. It is uncertain whether these effects should be attributed to chemical contamination or the physical characteristics of the sediment. For example, several of the sites which had low survival of *H. azteca* and *Hexagenia* were very sandy (e.g., AR1 and AR8). *Hexagenia* is a mayfly which burrows into the sediment and filters water and food particles through the burrows that it creates within the sediment. Sediments with a high sand content which tend to collapse are not preferred by this species as they can cause death. The high sand content of AR1 and AR8 could therefore possibly account for the low level of survival of this species in sediments collected from these two sites. Burrowing mayflies do not normally inhabit sediment with a high sand content.

The amphipod, *H. azteca,* also does not tolerate a high sand content (personal observation, K.Day). Percent survival and growth were reduced at these same two sites, AR1 and AR8, as well as AR3 and AR5. Results from AR1 were statistically significant compared to all other stations. In addition, the low level of growth recorded for this species was below the 5th percentile of the normal distribution of growth in 258 clean sediments from the Great Lakes.

Reproduction by the tubificid worm, *T. tubifex*, was also reduced at these two sites AR1 and AR8. Oligochaete worms ingest sediment to extract nutrients and bacteria from the organic material associated with the particles of sediment as a source of food. A sediment with a high sand content is not as nutritious as one with a large organic content and bacterial growth will be poorer in this type of sediment. The lower nutritive value could possibly result in lower reproduction.

In addition to a high sand content, several of the sites which caused a reduction in sublethal responses had elevated levels of some metals as well as phosphorus and nitrogen. Some of these levels were above the LEL set by the Province of Ontario for invertebrates. For example, sites AR5 and PR2 had elevated levels of copper and nickel. Sediments with a high sand content do not sorb contaminants as well as sediments with more organic material. Therefore, the presence of metals in these sediments with lower organic content may be more bioavailable to benthic invertebrates causing increased toxicity. Chemical analyses of sediments from these same locations showed levels of nitrogen to also be high and above the LEL (Table 4) which may also potentially cause a detrimental effect. As well, adverse effects caused by chemicals not measured in this study could be possible. Levels of polycyclic aromatic hydrocarbons (PAHs) were measured at these sites in a related study (MacInnis *et al.* 1995, Penders 1995), but were not considered high enough to be of concern (personnel communication, B. Brownlee).

No effects on *Chironomus* were evident in this study. Lower levels of growth were recorded at sites AR7, AR8, AR9, SR1 and PR2 but these levels were still higher than most recorded for clean reference sediments.. *Chironomus* is generally not affected by the physical conditions of sediment as much as the other three organisms used in toxicity tests (i.e., by large-sized particles; personnel observation, K.E.Day). Differences in growth at these sites may be due to unrecorded differences in the sediments or levels of copper and nickel which were above the LEL.

Reproduction by *Tubifex tubifex* appeared to be the more affected by whole sediments than suspended sediments as shown by the low values for mean cocoons produced per adult worm and mean offspring per adult worm at sites AR1, AR8 and AR9. In addition, site AR9 had delayed hatching of young from cocoons perhaps indicating an effect on embryogenesis. Exposure of adult worms to suspended sediments were had more variable results and few statistical differences among sites were recorded. Suspended sediment collected from AR6.1ss had greater negative effects on worm survival and reproduction than the duplicate sample AR6.2ss. Suspended solid samples are collected by centrifuging large volumes of water; therefore, "duplicate" samples could in fact be quite different because of the spatial heterogeneity of suspended material in the water column. All sites for suspended solids had higher mean offspring/adult worm than the levels from clean, reference sediments, indicating few toxic effects on reproduction.

There is evidence from past data that sediments from the oil sands area of the Athabasca River cause toxic effects on animals (Microtox^R studies- MacInnis *et al.* 1992, Brownlee *et al.* 1993; MFO induction- Brownlee *et al.* 1993). The sites AR6 (suspended solids only) and AR7 of the present study were in this area. Some effects on the growth of *Hexagenia* were observed at AR7 (see previous discussion pertaining the physical and chemical parameters of sediments), and negative trends (non-statistical) in reproduction were observed for *Tubifex* at AR6.1ss. However, these locations, in general, were not toxic to the other test animals. Metal levels were not high in whole sediments at AR7 as for other sites. Organic contaminants from oil sources could be present but were not measured in this study.

5.0 SUMMARY AND CONCLUSIONS

With the exception of *Chironomus*, effects on measured endpoints were observed in bioassays with some or all of the animals using whole sediments collected from sites AR1, AR5, AR8 and AR9. The causes of these effects may be due to elevated levels of some metals at some sites, and/or the sandy sediments. No major toxic responses were observed for *Chironomus*, although some relative growth differences existed among sites (AR7, AR8, AR9, SR1 and PR2). Worms exposed to suspended solids at sites AR5ss and AR6.1ss in the Athabasca River, and PR2ss in the Peace River, tended to show reduced reproduction. This is possibly due to elevated levels of certain metals (Cu and Ni) or sandy locations. Sites located in the oil sands area of the Athabasca River (AR6-suspended solids, and AR7) did not appear to have any toxic effects on most test animals. No further studies with whole sediments are recommended at this time.

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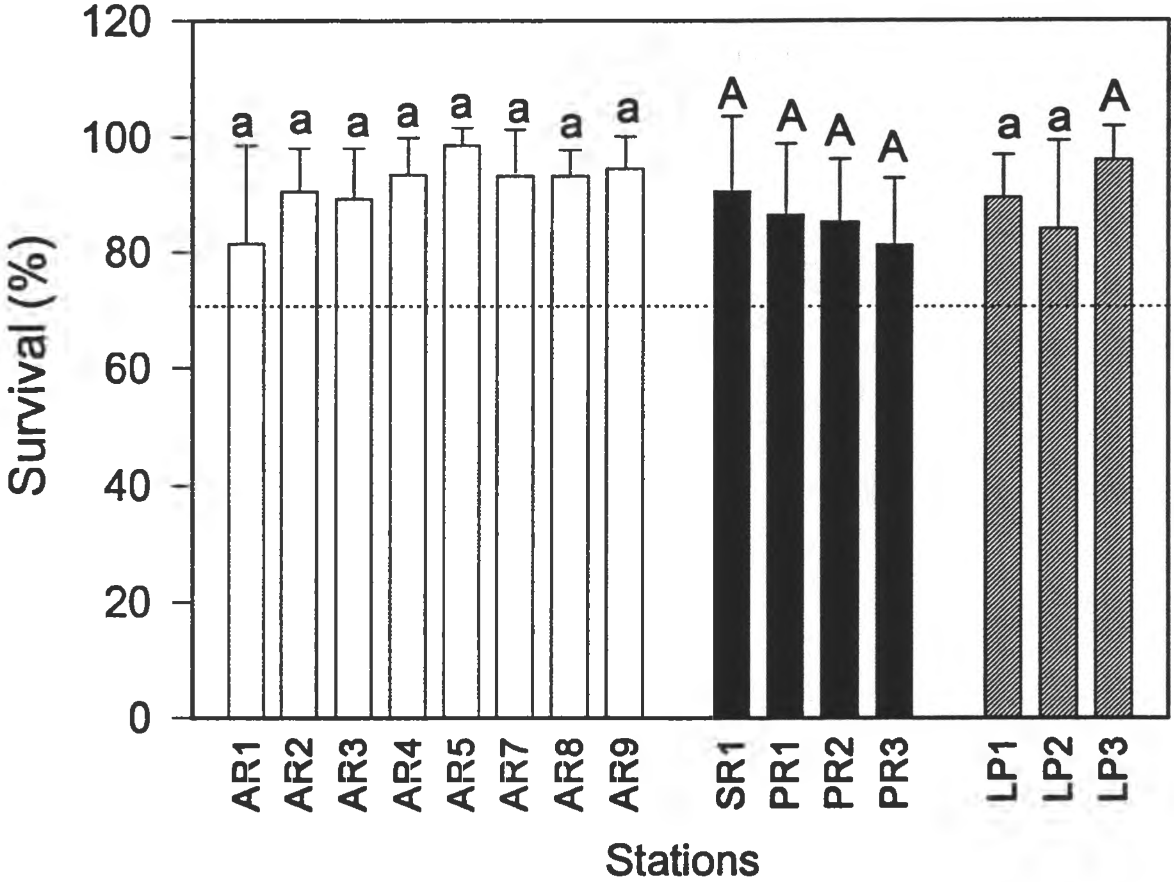
Figure 1.


Slave River
Lake Athabasca
Peace River
PR4
ALBERTA
AR8
AR7
PR3
Fort McMurray
AR6
Peace River
PR1
PR2
Peace River
SR2
Grande Prairie
Lesser Slave Lake
AR5
AR4
Wapiti River
SR1
Smoky River
AR3
AR9
AR2
Athabasca River
Edmonton
AR1
Calgary
Pulp Mills
Oil Sands Plants
Sampling Sites

Percent Survival of *C. riparius* in sediments from the Athabasca, Smoky, and Peace Rivers, 1995.



Increase in biomass of *C. riparius* in sediments from the Athabasca, Smoky and Peace Rivers, 1995.

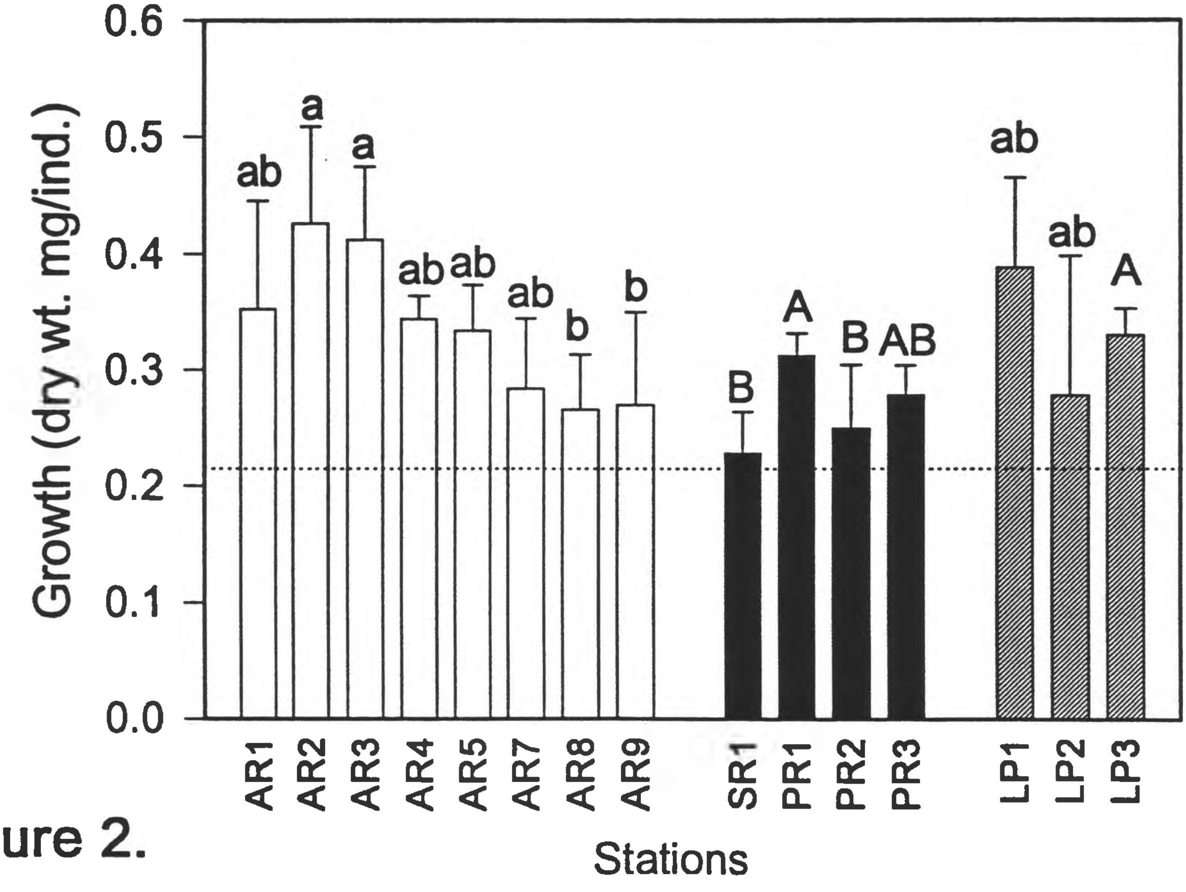
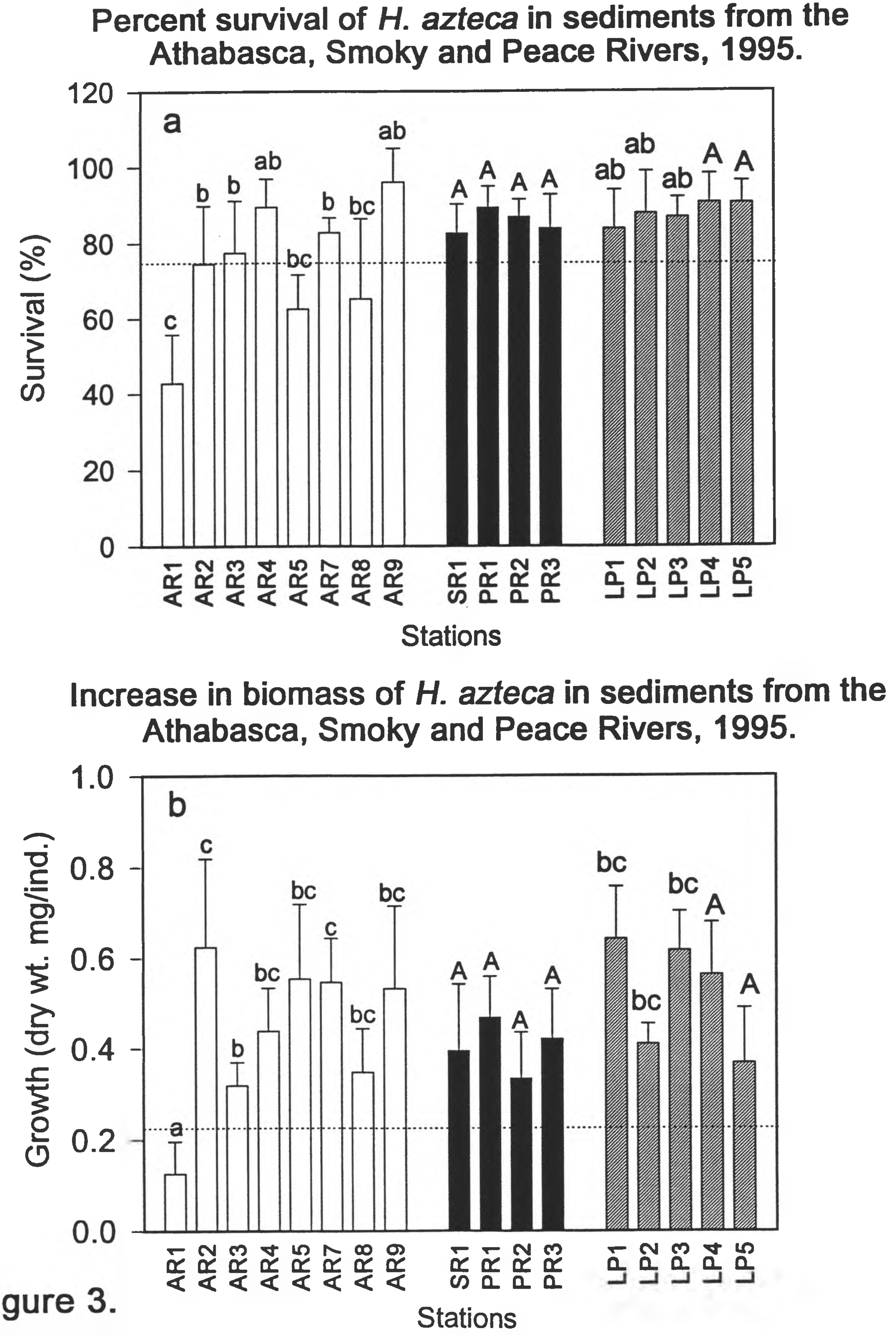
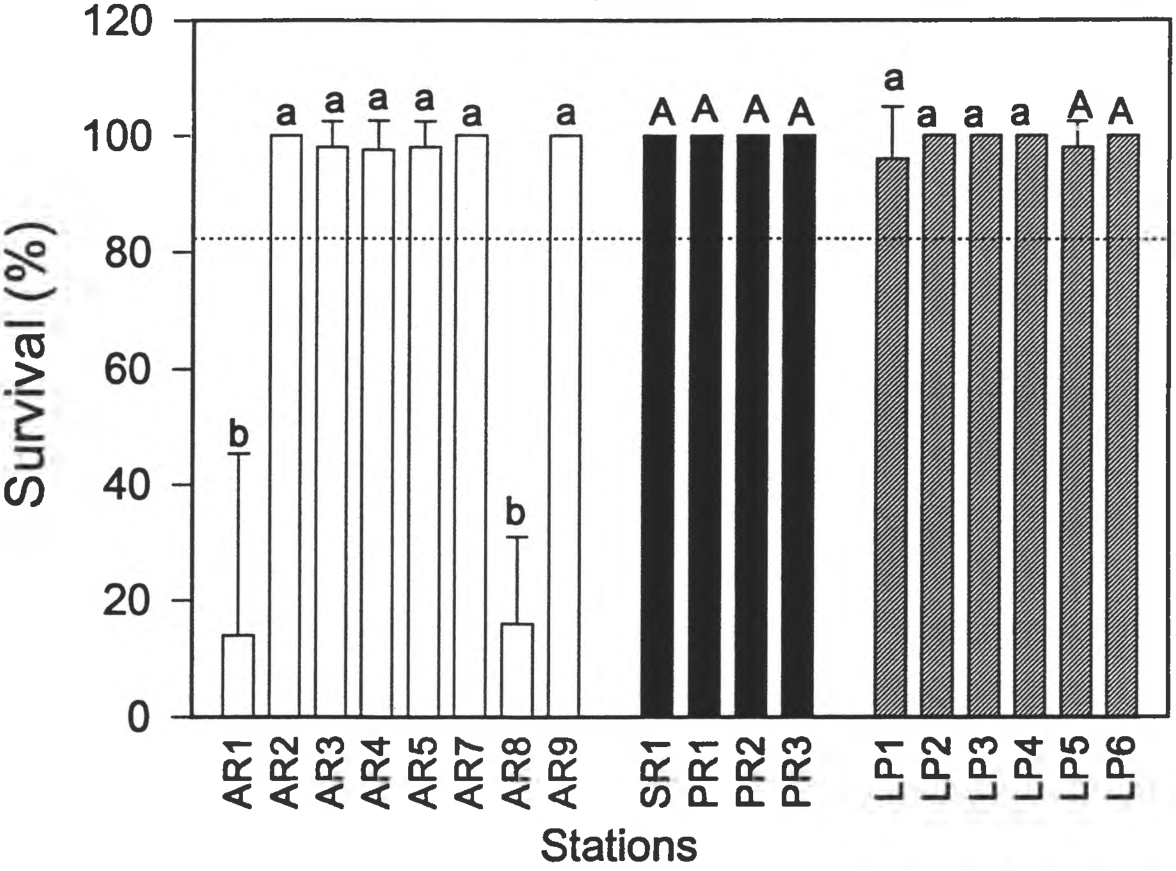


Figure 2.


Percent survival of *H. azteca* in sediments from the Athabasca, Smoky and Peace Rivers, 1995.

Increase in biomass of *H. azteca* in sediments from the Athabasca, Smoky and Peace Rivers, 1995.

Figure 3.


Percent Survival of *Hexagenia* spp. in sediments from the Athabasca, Smoky and Peace Rivers, 1995.

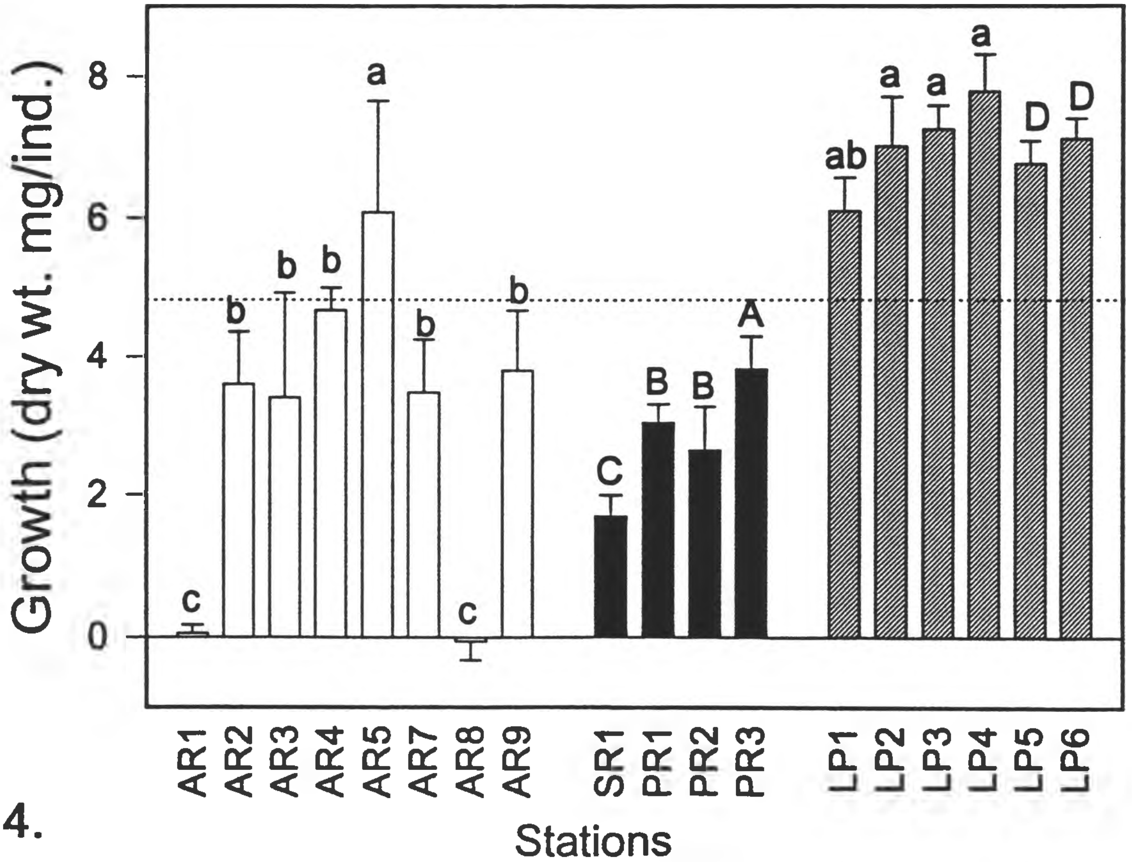

Increase/decrease in biomass of *Hexagenia* spp. in sediments from the Athabasca, Smoky and Peace Rivers, 1995

Figure 4.

Percent survival of adult *Tubifex tubifex* in whole sediments from the Athabasca, Smoky and Peace Rivers, 1995.

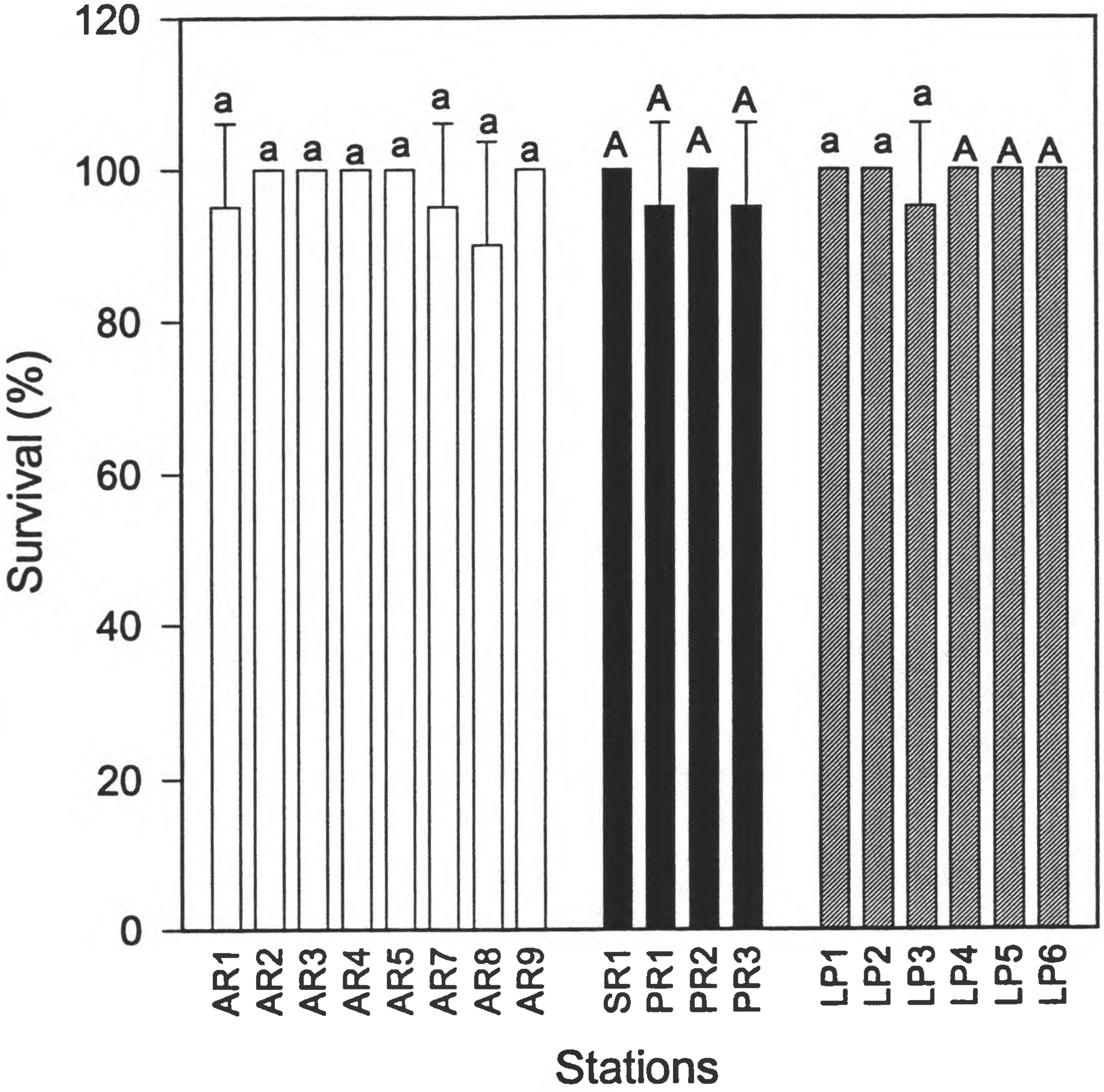


Figure 5.

Reproduction by *T. tubifex* in whole sediments from the Athabasca, Smoky and Peace Rivers, 1995.

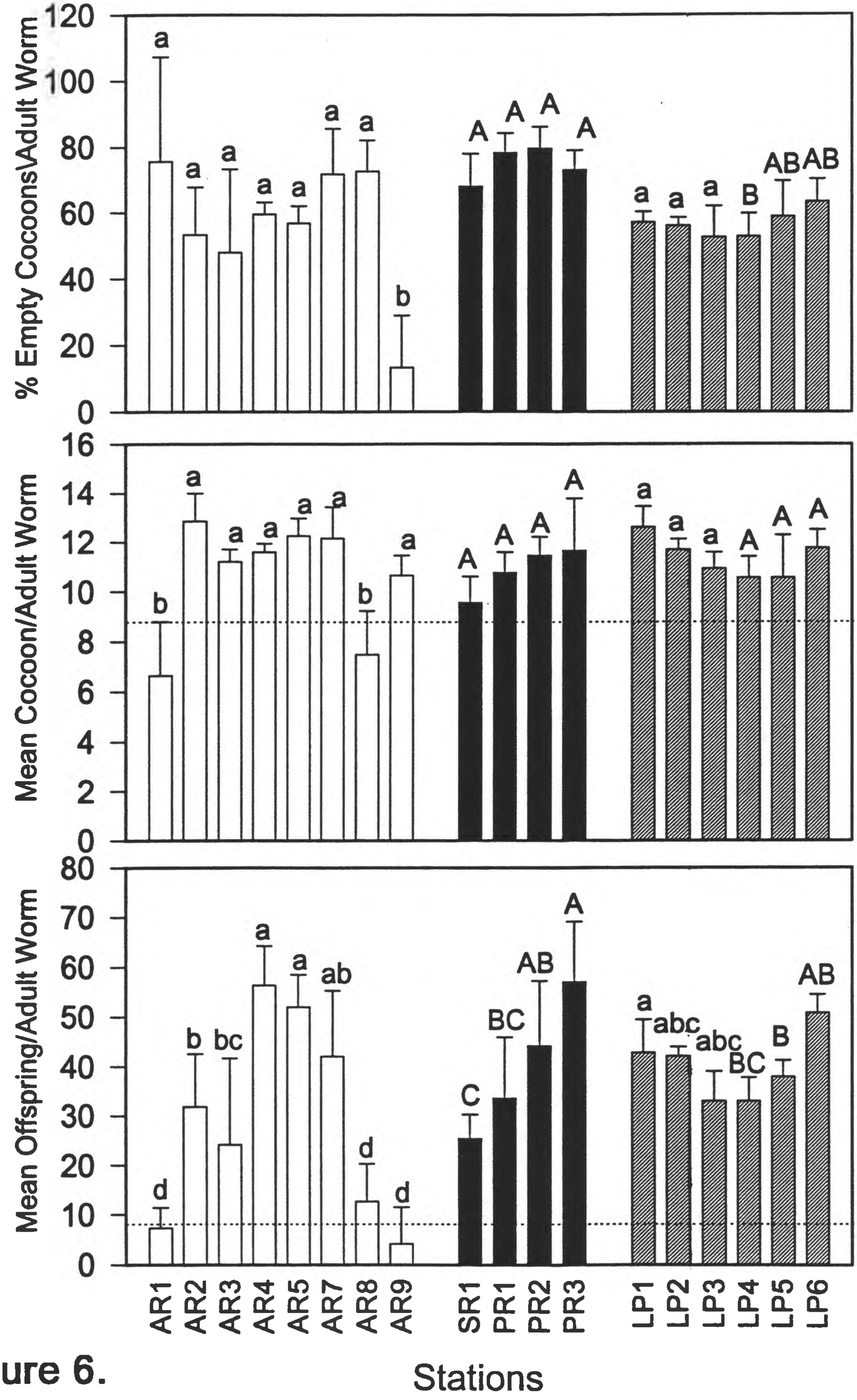


Figure 6.

Percent survival of adult *Tubifex tubifex* in suspended sediments from the Athabasca, Smoky and Peace Rivers, 1995.

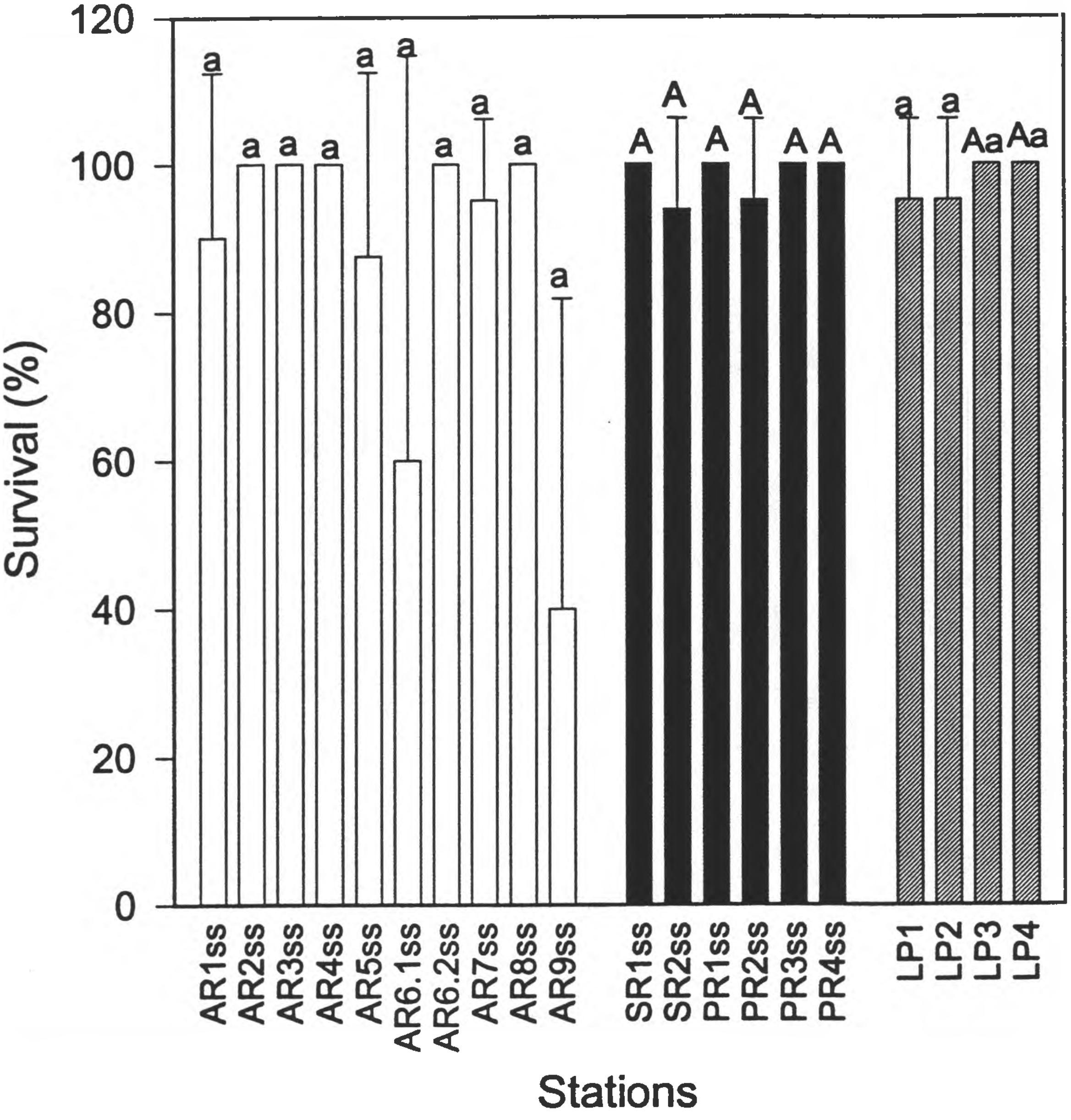
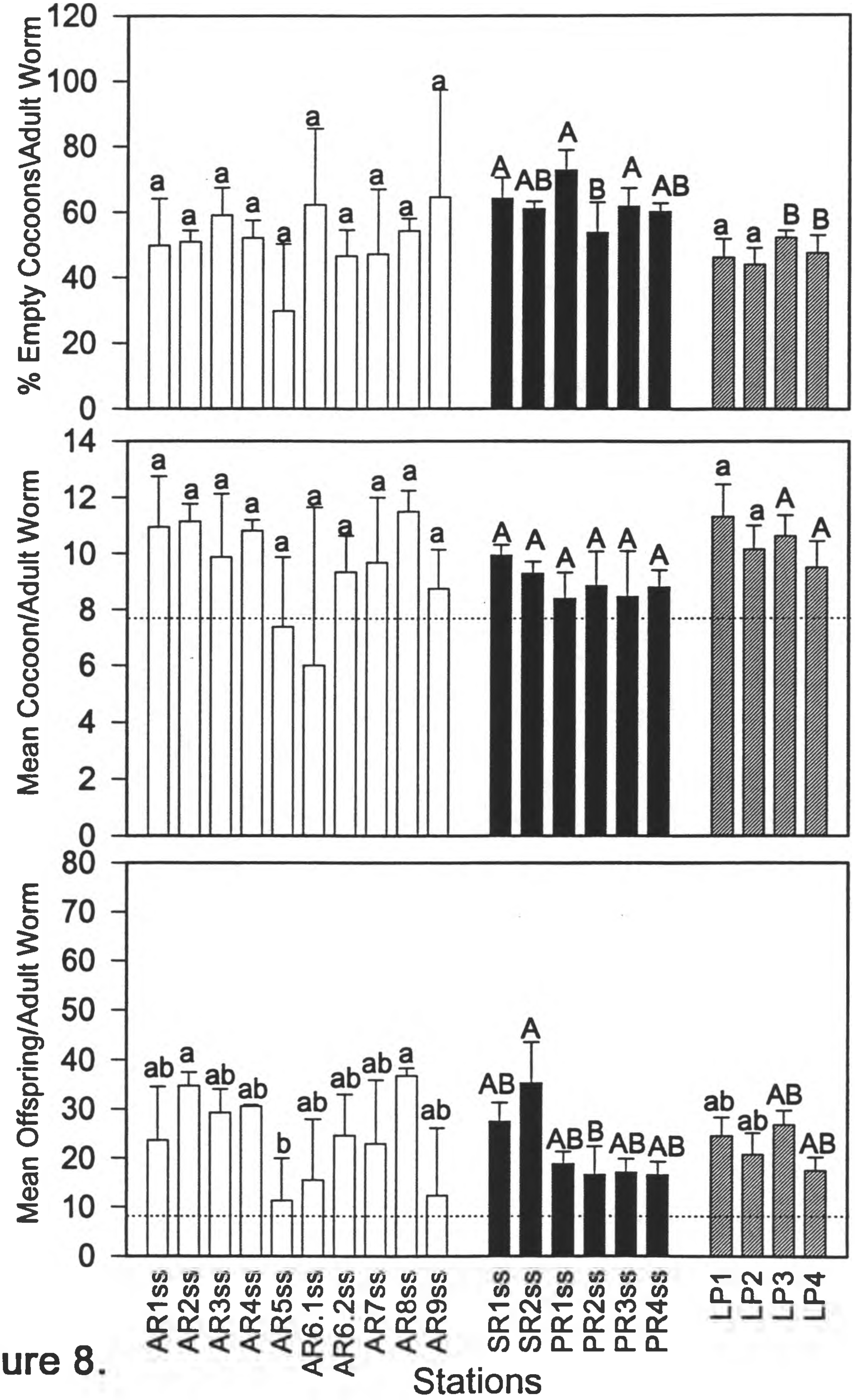


Figure 7.



Reproduction by *T. tubifex* in suspended sediments from the Athabasca, Smoky and Peace Rivers, 1995.

Figure 8.

Table 1a.

DATE	LOCATION	NAME	TURBIDITY	SUSPENDED SEDIMENT		BOTTOM SED.	VAN CEEA
				TIME CENT.	VOLUME CENT.		
June 8	Athabasca u/s Hinton	AR1	49	9.5 hours	6840 litres	5 bottom sediment (wading)	2 samples
June 9	Athabasca u/s Berland	AR2	50	7 hours	6720 litres	5 bottom sediment	no samples
June 10	Athabasca Windfall	AR3	58	8 hours	6720 litres	5 bottom sediment	no samples
June 12	Athabasca u/s Athabasca	AR4	130-150	5 hours	5400 litres	5 bottom sediment	2 samples
June 13	Athabasca d/s Alpac	AR5	150	4 hours	4320 litres	5 bottom sediment	no samples
June 14	Athabasca u/s Horse	AR6 Rep 1	160	4 hours	4320 litres	no bottom sediment	no samples
June 14	Athabasca u/s Horse	AR6 Rep 2	160	3 hours	3240 litres	no bottom sediment	no samples
June 16	Athabasca Mile 34	AR7	101	4 hours	4320 litres	5 bottom sediment	1 sample
June 17	Athabasca Mile 117	AR8	125	3.5 hours	3780 litres	5 bottom sediment	no samples
June 21	Athabasca Vega Ferry	AR9	35	8 hours	8640 litres	5 bottom sediment	no samples
June 22	Smoky Smoky Flats	SR1	>200	1.5 hours	1530 litres	5 bottom sediment (wading)	1 sample
June 23	Peace Peace River	PR1	>200	0.75 hours	810 litres	5 bottom sediment	no samples
June 24	Peace u/s Smoky	PR2	168	3 hours	3240 litres	5 bottom sediment	no samples
June 24	Smoky at mouth	SR2	>200	1.75 hours	1296 litres	no bottom sediment	no samples
June 25	Peace Notikewin	PR3	>200	2 hours	2196 litres	5 bottom sediment	2 samples
June 26	Peace Fort Vermillion	PR4	>200	5.5 hours	4056 litres	no bottom sediment	2 samples

Table 1b. Latitude and longitude co-ordinates for all sites in the Athabasca, Smoky, and Peace Rivers.

Site	Latitude N.	Longitude W.
AR1	52° 22' 30"	117° 36' 30"
AR2	54° 00' 00"	116° 48' 00"
AR3	54° 14" 00"	116° 05' 00"
AR4	54° 44' 00"	113° 19' 30"
AR5	54° 58' 50"	112° 43' 08"
AR6	56° 43' 05"	111° 24' 24"
AR7	57° 07' 36"	111° 35' 54"
AR8	58° 10' 09"	111° 21' 45"
AR9	54° 25' 30"	113° 31' 30"
SR1	54° 47' 00"	118° 35' 00"
PR1	56° 13' 00"	117° 20' 30"
PR2	56° 10' 30"	117° 24' 00"
SR2	56° 09' 45"	117° 23' 00"
PR3	57° 12' 00"	117° 05' 30"
PR4	58° 23' 30"	116° 00' 00"

Table 2. Particle Size Distribution for Whole Sediment Samples from NRBS:

Site	% Sand	% Silt	% Clay
AR1	88.08	11.92	-
AR2	43.72	43.26	13.01
AR3	60.84	33.05	6.1
AR4	36.49	36.87	26.64
AR5	16.14	55.30	28.56
AR7	37.08	41.01	21.92
AR8	99.35	0.01	0.54
AR9	41.89	38.15	19.96
SR1	65.90	24.95	7.85
PR1	26.32	51.97	21.71
PR2	16.5	40.65	42.85
PR3	18.96	53.89	27.16

Table 3. Particle Size Distribution for Suspended Sediment Samples from NRBS:

Site	% Sand	% Silt	% Clay
AR1SS	32.48	33.88	33.64
AR2SS	11.36	43.67	44.97
AR3SS	5.67	50.69	43.63
AR4SS	2.93	37.50	59.57
AR5SS	6.03	47.43	46.54
AR6-1SS	1.02	45.09	53.89
AR6-2SS	1.14	50.13	48.73
AR7SS	2.40	41.98	55.62
AR8SS	4.91	43.62	51.47
AR9SS	4.85	47.48	47.68
SR1SS	3.94	38.48	57.58
SR2SS	16.56	39.58	43.86
PR1SS	2.58	39.48	57.94
PR2SS	0.47	19.95	79.58
PR3SS	1.33	27.76	70.91
PR4SS	0.19	26.49	73.33

Table 4. Chemical parameters for sediments collected from the Athabasca, Smoky, and Peace Rivers, Alberta, 1995.

site	P PPM	N PPM	Cu PPM	Pb PPM	Zn PPM	Ni PPM	Cd PPM	Cr PPM	As PPM	% TOC	% LOI
AR1	509	134	5	11	22	8	<1	9	<5	0.04	22.6
AR2	605	613	8	12	36	14	<1	12	<5	1.02	21.5
AR3	603	698	9	11	42	15	<1	13	<5	1.03	15.8
AR4	584	852	14	12	53	20	<1	16	5	1.38	10.6
AR5	617	828	16	15	57	21	<1	16	<5	1.23	12.0
AR7	552	652	11	14	49	15	<1	12	<5	1.21	8.1
AR8	144	1600	4	4	11	6	<1	3	<5	0.32	1.5
AR9	547	664	12	12	48	17	<1	13	<5	1.11	11.9
SR1	685	1420	11	<1	47	19	<1	12	<5	0.47	7.0
PR1	693	1040	20	12	87	24	3	15	12	1.51	7.7
PR2	648	1220	27	12	106	32	<1	20	6	1.31	8.2
PR3	737	318	22	10	92	29	<1	16	11	1.71	8.3
LEL	600	550	16	31	120	16	0.6	26	6	1.00	-
SEL	2000	4800	110	250	820	75	10	110	33	10.0	-

Table 5. Chemical parameters for suspended sediments collected from the Athabasca, Smoky, and Peace Rivers, Alberta, 1995.

site	P PPM	N PPM	Cu PPM	Pb PPM	Zn PPM	Ni PPM	Cd PPM	Cr PPM	As PPM	% TOC	% LOI
AR1ss	540	502	10	14	38	15	<1	14	<5	0.82	22.1
AR2ss	541	1430	16	22	51	23	<1	18	<5	1.10	22.6
AR3ss	525	1160	16	17	55	22	<1	19	7	1.59	22.1
AR4ss	625	1330	21	19	70	28	<1	20	<5	1.76	16.0
AR5ss	613	1370	20	20	71	29	<1	20	<5	1.70	15.7
AR61ss	587	1680	22	28	76	30	<1	21	<5	1.84	16.8
AR62ss	581	1310	22	32	78	31	<1	21	<5	1.81	16.4
AR7ss	556	1300	21	18	80	29	<1	21	5	1.97	16.0
AR8ss	646	1530	21	23	77	30	1	21	<5	2.70	15.5
AR9ss	578	1150	19	12	62	27	<1	21	7	1.33	15.9
SR1ss	726	972	24	21	95	33	1	19	<5	1.72	13.0
SR2ss	559	699	23	19	82	31	<1	18	17	1.67	10.5
PR1ss	625	955	26	18	94	34	1	20	<5	1.60	11.1
PR2ss	844	1340	31	18	131	43	<1	22	9	1.70	10.8
PR3ss	637	1080	27	16	102	37	<1	21	6	1.57	11.6
PR4ss	868	1390	32	20	139	48	<1	23	<5	1.50	11.1
LEL	600	550	16	31	120	16	0.6	26	6	1.00	-
SEL	2000	4800	110	250	820	75	10	110	33	10.0	-

APPENDICES

Appendix A. Raw survival and growth data for C. riparius

Site	Survival	Mean	Std	Dry Wt	Mean	Std
AR1	60	81.4	17.2	0.47	0.35	0.09
	67			0.41		
	93			0.30		
	100			0.23		
	87			0.35		
AR2	80	90.6	7.5	0.57	0.43	0.08
	100			0.37		
	87			0.39		
	93			0.42		
	93			0.38		
AR3	100	89.2	8.9	0.40	0.41	0.06
	80			0.42		
	93			0.34		
	93			0.39		
	80			0.51		
AR4	93	93.4	6.5	0.32	0.34	0.02
	87			0.35		
	100			0.37		
	100			0.35		
	87			0.33		
long pt. 1	87	89.4	7.5	0.35	0.39	0.08
	80			0.48		
	100			0.34		
	87			0.31		
	93			0.46		
AR5	100	100.0	4.9	0.32	0.33	0.04
	93			0.37		
	100			0.30		
	100			0.29		
	107			0.38		
AR7	80	113.2	49.1	0.28	0.28	0.06
	100			0.32		
	200			0.19		
	93			0.28		
	93			0.35		
AR8	100	93.2	4.6	0.21	0.27	0.05
	87			0.33		
	93			0.28		
	93			0.28		
	93			0.23		
AR9	93	97.4	9.1	0.26	0.27	0.08
	107			0.33		
	87			0.18		
	107			0.21		
	93			0.37		
long pt. 2	100	84.0	15.3	0.25	0.28	0.12
	60			0.41		
	93			0.34		
	80			0.09		
	87			0.30		
SR1	100	90.6	13.1	0.25	0.23	0.04
	73			0.28		
	80			0.21		
	100			0.21		
	100			0.19		
PR1	93	86.4	12.6	0.30	0.31	0.02
	73			0.32		
	100			0.29		
	73			0.31		
	93			0.34		
PR2	100	85.2	11.0	0.21	0.25	0.05
	73			0.33		
	93			0.20		
	80			0.23		
	80			0.28		
PR3	67	81.2	11.7	0.31	0.28	0.03
	93			0.25		
	93			0.27		
	73			0.26		
	80			0.30		
long pt. 3	93	96.0	5.9	0.36	0.33	0.02
	87			0.30		
	100			0.33		
	100			0.32		
	100			0.34		

Appendix B. Raw survival and growth data for H. azteca

Site	Survival	Mean	Std	Dry Wt	Mean	Std
AR1	33	42.8	13.0	0.03	0.13	0.07
	47			0.13		
	27			0.21		
	47			0.17		
	60			0.09		
AR2	87	74.6	15.2	0.61	0.62	0.19
	93			0.51		
	60			0.88		
	73			0.74		
	60			0.38		
long pt. 1	73	83.8	10.2	0.77	0.64	0.12
	87			0.64		
	93			0.61		
	73			0.47		
	93			0.72		
AR3	73	77.4	13.7	0.32	0.32	0.05
	67			0.39		
	80			0.33		
	67			0.25		
	100			0.30		
AR4	100	89.4	7.5	0.37	0.44	0.10
	80			0.41		
	87			0.37		
	93			0.60		
	87			0.44		
long pt. 2	80	87.8	11.0	0.44	0.41	0.04
	100			0.42		
	73			0.46		
	93			0.38		
	93			0.35		
AR5	53	62.6	9.1	0.41	0.55	0.16
	73			0.44		
	67			0.79		
	67			0.66		
	53			0.47		
AR7	80	82.8	3.8	0.55	0.55	0.10
	80			0.43		
	87			0.53		
	80			0.70		
	87			0.52		
long pt. 3	87	86.8	5.1	0.58	0.62	0.08
	87			0.54		
	80			0.61		
	93			0.74		
AR8	60	65.2	21.2	0.30	0.35	0.10
	93			0.47		
	80			0.37		
	40			0.21		
	53			0.38		
AR9	100	96.0	8.9	0.59	0.53	0.18
	100			0.66		
	80			0.33		
	100			0.35		
	100			0.73		
SR1	93	82.6	7.6	0.39	0.39	0.15
	87			0.41		
	80			0.57		
	80			0.16		
	73			0.44		
PR1	80	89.2	5.8	0.42	0.47	0.09
	93			0.59		
	93			0.39		
	87			0.40		
	93			0.54		
PR2	93	86.8	4.6	0.15	0.33	0.10
	87			0.36		
	80			0.36		
	87			0.40		
	87			0.39		
long pt. 4	87	90.6	7.5	0.67	0.56	0.12
	93			0.43		
	100			0.58		
	93			0.68		
	80			0.46		
PR3	80	83.8	8.9	0.54	0.42	0.11
	93			0.27		
	80			0.34		
	93			0.47		
	73			0.48		
long pt. 5	93	90.4	5.8	0.34	0.37	0.12
	93			0.53		
	93			0.45		
	93			0.23		
	80			0.29		

Appendix C. Raw survival and growth data for Hexagenia

Site	Survival	Mean	Std	Growth	Mean	Std
AR1	0	14.0	31.3	0.00	0.05	0.12
	70			0.26		
	0			0.00		
	0			0.00		
	0			0.00		
AR2	100	100.0	0.0	4.29	3.59	0.80
	100			2.34		
	100			3.71		
	100			4.15		
	100			3.44		
long pt. 1	80	96.0	8.9	6.52	6.09	0.47
	100			6.00		
	100			6.53		
	100			5.38		
	100			6.00		
AR3	90	97.5	4.8	4.63	3.39	1.47
	100			1.67		
	100			2.55		
	100			4.72		
AR4	100	97.5	4.8	4.83	4.67	0.31
	100			4.40		
	100			4.41		
	90			5.05		
long pt. 2	100	100.0	0.0	5.99	7.00	0.68
	100			7.29		
	100			7.57		
	100			7.17		
AR5	100	98.0	4.5	5.27	6.07	1.58
	100			5.20		
	90			8.76		
	100			4.94		
	100			6.17		
AR7	100	100.0	0.0	4.05	3.47	0.76
	100			2.34		
	100			3.94		
	100			3.53		
long pt. 3	100	100.0	0.0	6.67	7.24	0.34
	100			7.23		
	100			7.41		
	100			7.44		
	100			7.47		
AR8	0	16.0	15.2	0.00	-0.06	0.27
	30			0.25		
	20			-0.03		
	0			0.00		
	30			-0.50		
AR9	100	100.0	0.0	3.11	3.80	0.88
	100			4.87		
	100			3.05		
	100			3.32		
	100			4.63		
long pt. 4	100	100.0	0.0	8.54	7.78	0.52
	100			7.58		
	100			8.03		
	100			7.58		
	100			7.17		
SR1	100	100.0	0.0	2.03	1.70	0.29
	100			1.46		
	100			1.34		
	100			1.88		
	100			1.81		
PR1	100	100.0	0.0	2.60	3.03	0.27
	100			3.21		
	100			3.15		
	100			3.27		
	100			2.92		
long pt. 5	100	98.0	4.5	6.89	6.76	0.32
	90			7.14		
	100			6.64		
	100			6.84		
	100			6.27		
PR2	100	100.0	0.0	1.64	2.63	0.63
	100			3.38		
	100			2.67		
	100			2.64		
	100			2.83		
PR3	100	100.0	0.0	4.35	3.81	0.48
	100			3.38		
	100			3.31		
	100			3.76		
	100			4.26		
long pt. 6	100	100.0	0.0	6.80	7.10	0.29
	100			7.37		
	100			7.36		
	100			7.19		
	100			6.80		

Appendix D. Raw data for survival and reproduction by T. Tubifex, whole sediment.

Site	Adults	% Survival	ean % Survival		Empty Cocs.	Tot.Cocs	% empty	mean%empt	std	Cocs/adult	Mean	STD.	Tot Off.	Totoff/adult	Mean	std
AR1	4	100	95	11.18034	22	22	100	77.96596	34.08627	5.5	6.65	2.147673	46	11.5	7.366667	4.056288
	4	100			20	28	71.42857			7			44	11		
	3	75			25	30	83.33333			10			13	4.333333		
	4	100			4	17	23.52941			4.25			9	2.25		
	4	100			29	26	111.5385			6.5			31	7.75		
AR2	4	100	100		26	48	54.16667	53.28435	14.58772	12	12.85	1.140175	166	41.5	31.8	10.71418
	4	100			29	59	49.15254			14.75			139	34.75		
	4	100			29	52	55.76923			13			123	30.75		
	4	100			37	50	74			12.5			152	38		
	4	100			16	48	33.33333			12			56	14		
long pt. 1	4	100	100		28	53	52.83019	57.09761	3.214697	13.25	12.6	0.858778	212	53	42.8	6.678791
	4	100			27	48	56.25			12			157	39.25		
	4	100			27	47	57.44681			11.75			172	43		
	4	100			28	49	57.14286			12.25			140	35		
	4	100			34	55	61.81818			13.75			175	43.75		
AR3	4	100	100		20	48	41.66667	47.90956	25.48296	12	11.2	0.512348	189	47.25	24.2	17.42609
	4	100			36	43	83.72093			10.75			114	28.5		
	4	100			8	43	18.60465			10.75			37	9.25		
	4	100			15	45	33.33333			11.25			126	31.5		
	4	100			28	45	62.22222			11.25			18	4.5		
AR4	4	100	100		25	47	53.19149	59.5065	3.645107	11.75	11.6	0.33541	190	47.5	56.35	7.879166
	4	100			27	45	60			11.25			196	49		
	4	100			29	48	60.41667			12			233	58.25		
	4	100			29	47	61.70213			11.75			263	65.75		
	4	100			28	45	62.22222			11.25			245	61.25		
long pt. 2	4	100	100		25	45	55.55556	56	2.459941	11.25	11.7	0.410792	174	43.5	42.1	1.850676
	4	100			25	48	52.08333			12			160	40		
	4	100			27	48	56.25			12			164	41		
	4	100			26	45	57.77778			11.25			178	44.5		
	4	100			28	48	58.33333			12			166	41.5		
AR5	4	100	100		29	46	63.04348	56.7411	5.234863	11.5	12.25	0.728869	244	61	52	6.48797
	4	100			31	53	58.49057			13.25			204	51		
	4	100			23	47	48.93617			11.75			177	44.25		
	4	100			28	48	58.33333			12			222	55.5		
	4	100			28	51	54.90196			12.75			193	48.25		
AR7	4	100	95	11.18034	34	51	66.66667	71.79199	13.77771	12.75	12.15	1.282088	189	47.25	42.03333	13.30787
	3	75			26	36	72.22222			12			95	31.66667		
	4	100			41	43	95.34884			10.75			98	24.5		
	4	100			28	45	62.22222			11.25			205	51.25		
	4	100			35	56	62.5			14			222	55.5		
long pt. 3	3	75	95	11.2	19	34	55.88235	52.46694	9.567678	11.33333	11.01667	0.569478	115	38.33333	33.06667	5.959178
	4	100			22	44	50			11			127	31.75		
	4	100			27	41	65.85366			10.25			117	29.25		
	4	100			17	43	39.53488			10.75			104	26		
	4	100			24	47	51.06383			11.75			160	40		
AR8	3	75	92.85714	13.89306	15	17	88.23529	72.56729	9.55616	5.666667	7.5	1.739053	27	9	12.68333	7.573345
	3	75			20	28	71.42857			9.333333			74	24.66667		
	4	100			18	29	62.06897			7.25			24	6		
	4	100			26	37	70.27027			9.25			62	15.5		
	4	100			17	24	70.83333			6			33	8.25		
AR9	4	100	100		16	41	39.02439	13.23514	15.58915	10.25	10.65	0.80234	7	1.75	4.15	7.375212
	4	100			0	45	0			11.25			0	0		
	4	100			1	38	2.631579			9.5			0	0		
	4	100			4	43	9.302326			10.75			7	1.75		
	4	100			7	46	15.21739			11.5			69	17.25		

long pt. 4	4	100	100	25	43	58.13953	52.90646	6.97958	10.75	10.55	0.855132	148	37	33.05	4.688417
	4	100		24	46	52.17391			11.5			151	37.75		
	4	100		16	37	43.24324			9.25			114	28.5		
	4	100		25	41	60.97561			10.25			111	27.75		
	4	100		22	44	50			11			137	34.25		
SR1	4	100	100	19	34	55.88235	67.8928	10.11368	8.5	9.55	1.051784	88	22	25.45	4.877884
	4	100		28	39	71.79487			9.75			131	32.75		
	4	100		28	37	75.67568			9.25			113	28.25		
	4	100		21	36	58.33333			9			88	22		
	4	100		35	45	77.77778			11.25			89	22.25		
PR1	4	100	100	34	43	79.06977	78.21593	5.989109	10.75	10.75	0.847791	61	15.25	33.58333	12.27987
	4	100		38	44	86.36364			11			110	27.5		
	4	100		29	39	74.35897			9.75			151	37.75		
	3	75		29	36	80.55556			12			137	45.66667		
	4	100		29	41	70.73171			10.25			167	41.75		
long pt. 5	4	100	100	23	43	53.48837	58.90882	10.72532	10.75	10.6	1.737455	166	41.5	38	3.235545
	4	100		25	50	50			12.5			144	36		
	4	100		24	31	77.41935			7.75			163	40.75		
	4	100		25	44	56.81818			11			135	33.75		
	4	100		25	44	56.81818			11			152	38		
PR2	4	100	100	38	43	88.37209	79.59922	6.553457	10.75	11.45	0.758288	130	32.5	44.15	13.08697
	4	100		33	43	76.74419			10.75			110	27.5		
	4	100		35	49	71.42857			12.25			207	51.75		
	4	100		35	45	77.77778			11.25			217	54.25		
	4	100		41	49	83.67347			12.25			219	54.75		
PR3	4	100	100	24	33	72.72727	73.01787	5.965124	8.25	11.65	2.125735	194	48.5	57.08333	12.01012
	3	75		27	39	69.23077			13			227	75.66667		
	4	100		40	48	83.33333			12			228	57		
	4	100		31	45	68.88889			11.25			179	44.75		
	4	100		39	55	70.90909			13.75			238	59.5		
long pt. 6	4	100	100	34	51	66.66667	63.4377	6.814027	12.75	11.75	0.728869	221	55.25	50.9	3.688276
	4	100		28	45	62.22222			11.25			207	51.75		
	4	100		32	44	72.72727			11			212	53		
	4	100		30	49	61.22449			12.25			194	48.5		
	4	100		25	46	54.34783			11.5			184	46		

Appendix E. Raw data for survival and reproduction by T. tubifex, suspended sediments.

Site	Adults	% Survival	ean % Survival		Empty Cocs.	Tot.Cocs	% empty	mean%empt	std	Cocs/adult	Mean	STD.	Tot Off.	Totoff/adult	Mean	std
AR1SS	4	100	90	22.36068	24	44	54.54545	49.74599	14.40748	11	10.95	1.806239	116	29	23.65	10.94532
	4	100			32	51	62.7451			12.75			110	27.5		
	4	100			26	48	54.16667			12			102	25.5		
	2	50			4	16	25			8			9	4.5		
	4	100			23	44	52.27273			11			127	31.75		
AR2SS	4	100	100		25	46	54.34783	51.01032	3.445691	11.5	11.15	0.627495	141	35.25	34.75	2.766993
	4	100			20	41	48.78049			10.25			142	35.5		
	4	100			24	47	51.06383			11.75			129	32.25		
	4	100			25	46	54.34783			11.5			155	38.75		
	4	100			20	43	46.51163			10.75			128	32		
long pt. 1	4	100	95	11.18034	19	46	41.30435	46.15063	5.716043	11.5	11.31667	1.164283	87	21.75	24.63333	3.715863
	4	100			18	39	46.15385			9.75			82	20.5		
	3	75			19	34	55.88235			11.33333			89	29.66667		
	4	100			23	52	44.23077			13			107	26.75		
	4	100			19	44	43.18182			11			98	24.5		
AR3SS	4	100	100		25	48	52.08333	63.05025	17.15152	12	9.87	2.254884	120	30	29.18	4.865003
	5	100			27	53	50.9434			10.6			152	30.4		
	4	100			25	28	89.28571			7			141	35.25		
	4	100			23	32	71.875			8			87	21.75		
	4	100			24	47	51.06383			11.75			114	28.5		
AR4SS	4	100	100		20	44	45.45455	52.03824	5.351887	11	10.8125	0.375	124	31	30.5625	0.314576
	4	100			25	45	55.55556			11.25			121	30.25		
	4	100			21	42	50			10.5			122	30.5		
	4	100			24	42	57.14286			10.5			122	30.5		
long pt. 2	3	75	95	11.18034	10	26	38.46154	43.96778	5.021727	8.666667	10.13333	0.875198	43	14.33333	20.86667	4.260445
	4	100			20	42	47.61905			10.5			95	23.75		
	4	100			17	44	38.63636			11			75	18.75		
	4	100			19	41	46.34146			10.25			97	24.25		
	4	100			20	41	48.78049			10.25			93	23.25		
AR5SS	2	50	70	44.72136	0	8	0	29.67314	20.48856	4	7.375	2.49583	0	0	11.3125	8.634656
	4	100			16	38	42.10526			9.5			58	14.5		
	4	100			16	36	44.44444			9			82	20.5		
	4	100			9	28	32.14286			7			41	10.25		
	0	0														
AR61SS	0	0	60	54.77226	1	1	100	62.33333	23.02361	0	8	5.656854	1	1	15.5	12.36047
	0	0			2	3	66.66667			0			4	4		
	4	100			21	48	43.75			12			114	28.5		
	4	100			18	32	56.25			8			77	19.25		
	4	100			18	40	45			10			99	24.75		
AR62SS	4	100	100	0	20	41	48.78049	46.5253	8.018091	10.25	9.35	1.282088	124	31	24.6	8.434675
	4	100			21	37	56.75676			9.25			134	33.5		
	4	100			18	38	47.36842			9.5			89	22.25		
	4	100			10	29	34.48276			7.25			48	12		
	4	100			19	42	45.2381			10.5			97	24.25		
AR7SS	3	75	96.42857	11.18034	2	17	11.76471	47.18688	19.877	5.666667	9.683333	2.329908	4	1.333333	22.91667	12.99132
	4	100			24	43	55.81395			10.75			132	33		
	4	100			27	46	58.69565			11.5			121	30.25		
	4	100			21	39	53.84615			9.75			81	20.25		
	4	100			24	43	55.81395			10.75			119	29.75		

AR8SS			100					54.31894	3.798869		11.5	0.75			36.75	1.63936
	4	100			24	43	55.81395			10.75			153	38.25		
	4	100			23	46	50			11.5			148	37		
	4	100			28	49	57.14286			12.25			140	35		
AR9SS	2	50	40	41.833	7	17	41.17647	64.65806	32.72165	8.5	10.75	1.391941	28	14	12.35	13.82208
	2	50			5	15	33.33333			7.5			17	8.5		
	0	0			1	1	100						0	0		
	0	0			2	2	100						4	4		
	4	100			20	41	48.78049			10.25			141	35.25		
SR1SS								65.9332	6.517956		9.833333	0.381881			27.5	3.848701
	4	100	100		30	41	73.17073			10.25			106	26.5		
	4	100			23	38	60.52632			9.5			127	31.75		
	4	100			25	39	64.10256			9.75			97	24.25		
SR2SS	3	75	100		17	29	58.62069	61.0238	2.319311	9.666667	9.291667	0.399653	142	47.33333	35.27083	8.326768
	4	100			22	37	59.45946			9.25			133	33.25		
	4	100			22	35	62.85714			8.75			113	28.25		
	4	100			24	38	63.15789			9.5			129	32.25		
PR1SS	8	100	100		51	72	70.83333	62.34677	11.43287	9	8.633333	1.052224	152	19	17.7625	4.356688
	8	100			51	75	68			9.375			161	20.125		
	8	100			45	68	66.17647			8.5			168	21		
	8	100			40	56	71.42857			7			116	14.5		
	8	100			51	65	78.46154			8.125			158	19.75		
PR2SS	4	100	95	11.18034	19	35	54.28571	52.94027	6.408609	8.75	9.908333	1.507927	56	14	21.75	6.88295
	4	100			11	28	39.28571			7			45	11.25		
	4	100			22	35	62.85714			8.75			56	14		
	4	100			23	38	60.52632			9.5			72	18		
	3	75			16	31	51.6129			10.33333			78	26		
LP3	4	100	100		21	38	55.26316	52.16697	2.276565	9.5	10.95	0.942072	91	22.75	26.85	2.907963
	4	100			22	44	50			11			102	25.5		
	4	100			23	43	53.48837			10.75			121	30.25		
	4	100			23	46	50			11.5			115	28.75		
	4	100			25	48	52.08333			12			108	27		
PR3SS	5	100	100		21	34	61.76471	65.77087	3.989087	6.8	8.46	1.630337	73	14.6	17.12	2.836723
	4	100			21	32	65.625			8			66	16.5		
	4	100			19	30	63.33333			7.5			64	16		
	4	100			29	44	65.90909			11			66	16.5		
	4	100			26	36	72.22222			9			88	22		
PR4SS	4	100	100		20	35	57.14286	60.12408	2.51535	8.75	8.8	0.622495	69	17.25	16.65	2.661062
	4	100			19	32	59.375			8			69	17.25		
	4	100			21	35	60			8.75			73	18.25		
	4	100			25	39	64.10256			9.75			74	18.5		
	4	100			21	35	60			8.75			48	12		
LP4	4	100	100		13	34	38.23529	47.64706	5.261336	8.5	9.5	0.935414	57	14.25	17.5	2.709935
	4	100			18	36	50			9			76	19		
	4	100			19	38	50			9.5			68	17		
	4	100			19	38	50			9.5			64	16		
	4	100			22	44	50			11			85	21.25		

NORTHERN RIVER BASINS STUDY

APPENDIX F - TERMS OF REFERENCE

2326-E1: Ecotoxicology of Suspended and Bottom Sediments - Peace and Athabasca Rivers

I. BACKGROUND AND OBJECTIVES

Scientists have been conducting an ecotoxicology study of the lower Athabasca River (Figure 1) as part of a project funded by the Program on Energy Research and Development (PERD). Surveys carried out from 1990-93 suggest a natural or background source of toxicity within the oil sands area. Organic solvent extracts of suspended sediment collected from the Athabasca River in 1990 showed increasing response in the Microtox® test with distance downstream from Hinton (MacInnis *et al.* 1992, Brownlee *et al.* 1993). The same general pattern was also exhibited in an intensive survey (five-point transects at seven locations) conducted in 1993 (MacInnis *et al.* 1994). In addition, goldeye collected within the oil sands area in 1991 showed higher levels of hepatic mixed function oxygenase activity, a measurable biochemical response caused by foreign compounds, than individuals collected at an upstream site near Athabasca (Brownlee *et al.* 1993).

In 1993, as part of the Northern River Basins Study project 2326-C1, bottom sediment samples were collected at eight sites on the upper Athabasca River between Hinton and Whitecourt. These samples were tested for toxicity under controlled laboratory conditions using a battery of tests with four species of invertebrates. The results were all negative except for two sites which showed a weak response to the *Tubifex* test (Day and Reynoldson 1994). *Tubifex* is a bottom-dwelling oligochaete worm, and at these sites *Tubifex* reproduction was impaired by 10-30% of other control and experimental sites.

In 1994, as part of the PERD project, a 500 mL sample of suspended sediment was collected from the Athabasca River immediately upstream of Fort McMurray and subsequently tested for toxicity to *Tubifex*. This sample showed a high level of acute toxicity; 0% survival in three of five replicates and mean survival of 25% (Reynoldson, pers. comm.).

II. GENERAL REQUIREMENTS

Fifteen samples of suspended and depositional sediments will be collected from 14 sites in the NRBS study area (Table 1). Nine sites will be sampled on the Athabasca River from upstream Hinton to Wood Buffalo National Park (Figure 1). The site immediately upstream of Fort McMurray is important for distinguishing between natural and industrial sources of toxicity in the oil sands area, so it will be replicated. Five additional sites will be sampled, two on the Smoky River and three on the Peace River (Figure 1). Note that the location of sample sites are subject to minor changes due to operational considerations. The collections will be carried out in June, 1995, using an Alfa-Laval centrifuge for suspended sediments and a mini-Ponar sampler for depositional sediments. Sediments will tested for chronic toxicity using as many as four species of invertebrates in the laboratory, and saved for any subsequent contaminant analyses which may be warranted by the results.

Table 1. Proposed sampling sites for suspended sediments in the Athabasca and Peace rivers, May-June 1995.

River System	Site
Athabasca River	upstream Hinton
	downstream Hinton @ Berland River
	downstream Hinton @ Windfall bridge
	downstream Whitecourt @ Vega ferry
	upstream Athabasca
	downstream Alpac @ Calling River
	upstream Fort McMurray (two replicates)
	upstream Fort MacKay
	Wood Buffalo National Park
Peace-Smoky rivers	Smoky River upstream Wapiti River
	Smoky River @ Watino
	Peace River @ Dunvegan bridge
	Peace River @ Notikewin
	Peace River @ Fort Vermilion

The methodologies to be employed for chronic toxicity testing of the sediments is to follow those used by Day and Reynoldson (1995) for NRBS project 2326-C1.

1) Five replicate samples of bottom sediment and a single sample of suspended sediment will be collected at the 14 river sites. These will be placed in plastic bags and held at 4°C before chronic toxicity testing.

2) Before being subjected to chronic toxicity testing, the sediments will be sieved, and submitted for particle size and metals analysis.

3) Depositional sediments will be tested in the laboratory with the same four organisms used by Day and Reynoldson for the 1993 sample set; a midge larva (*Chironomus riparius*), an amphipod (*Hyalella azteca*), a mayfly (*Hexagenia* spp.) and an oligochaete worm (*T. tubifex*). The toxicity of suspended sediments will be tested using the *Tubifex* test.

4) Culture of *C. riparius* are to be conducted according to the ASTM (1992) procedure. Culture of *H. azteca* are to be conducted according to the procedure described in Borgmann *et al* (1989). Eggs of the mayfly *Hexagenia* spp. are to be

collected and organisms are to be cultured using the procedure of Hanes and Ciborowski (1992) and Bedard *et al* (1992).

5) Tests with *H. azteca*, *C. riparius* and *T. tubifex* are to be conducted in 250 glass beakers containing 60 to 100 mL of sieved (500 μm), homogenized sediment with approximately 100 to 140 mL of overlying carbon-filtered, dechlorinated and aerated Lake Ontario water. Tests with the mayfly, *Hexagenia*, are to be conducted in 1.0 L glass jars with 150 mL of test sediment and 850 mL overlying water. The sediment is allowed to settle for 24 h prior to the addition of animals. Test are to be initiated with the random addition of 15 organisms per beaker for *H. azteca* and *C. riparius*, 10 organisms per beaker for *Hexagenia* spp. and 4 organisms per beaker for *T. tubifex*. Juveniles of *H. azteca* are to be 3 to 7 d old at test initiation; *C. riparius* larvae are first instars and approximately 3 d post-oviposition; *Hexagenia* nymphs are 1.5 to 2 months old (approximately 5 to 10 mg wet weight) and *T. tubifex* adults are 8-9 weeks old. Tests are to be conducted at 23±1°C with a 16L:8D photoperiod. Tests are to be static with the periodic addition of distilled water to replace water lost during evaporation. Each beaker should be covered with a plastic petri dish with a central hole for aeration using a Pasteur pipette and air line. Tests are to be terminated after 10 d for *C. riparius*, 21 d for *Hexagenia* and 28 d for *H. azteca* and *T. tubifex*. Endpoints to be measured in the tests are survival and growth (mean dry weight in mg) for *H. azteca*, *C. riparius* and *Hexagenia*, and survival and production of cocoons/young for *T. tubifex*,.

III. REPORTING REQUIREMENTS

1. Five copies of a report containing the preliminary results are to be submitted to the Component Coordinator by **October 1, 1995**.

2. Ten copies of the Draft Report along with an electronic version are to be submitted to the Component Coordinator by **October 30, 1995**. The structure and content of the report should be similar to that found in Day and Reynoldson (1995). The report should include a basin(s) map of the sediment sampling locations, detailed maps of each sampling site, and appropriate statistical analyses for comparisons of the responses to toxicity testing.

3. Three weeks after the receipt of review comments on the draft report, the Contractor is to provide the Component Coordinator with two unbound, camera ready copies and ten cerlox bound copies of the final report along with an electronic version.

4. The Contractor is to provide draft and final reports in the style and format outlined in the NRBS document, "A Guide for the Preparation of Reports," which will be supplied upon execution of the contract.

   The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Report Summary, Table of Contents, List of Tables, List of Figures and an Appendix with the Terms of Reference for this project.

Text for the report should be set up in the following format:

a) Times Roman 12 point (Pro) or Times New Roman (WPWIN60) font.
b) Margins; are 1" at top and bottom, 7/8" on left and right.
c) Headings; in the report body are labelled with hierarchical decimal Arabic numbers.
d) Text; is presented with full justification; that is, the text aligns on both left and right margins.
e) Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

- If photographs are to be included in the report text they should be high contrast black and white.
- All tables and figures in the report should be clearly reproducible by a black and white photocopier.
- Along with copies of the final report, the Contractor is to supply an electronic version of the report in Word Perfect 5.1 or Word Perfect for Windows Version 6.0 format.
- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Project Liaison Officer along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

5. All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E00, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced.

6. All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

7. A presentation package of 35 mm slides is to comprise of one original and four duplicates of each slide.

IV. DELIVERABLES

1. A Level II interpretive report that presents the methodologies and results of the sediment collections, particle size determination, and metals and toxicity testing in the laboratory.

2. Ten to tewnty-five 35 mm slides that can be used at public meetings to summarize the project, methods and key findings.

V. CONTRACT ADMINISTRATION

This project has been proposed by the Contaminants Component of NRBS.

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Please contact the Component Coordinator on administrative matters.

VI. LITERATURE CITED

American Society for Testing and Materials (ASTM). 1992. Standard Guide for Conducting Sediment Toxicity Tests with Freshwater Invertebrates. ASTM 11.04 1992. Annual Book of ASTM Standards. American Society for Testing and Materials, Philadelphia, PA, pp. 1116-1138.

Bedard, D., A. Hayton and D. Persuad. 1992. Ontario Ministry of the Environment Laboratory Sediment Biological Testing Protocol. Water Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario. 26 pp.

Borgmann, U., K. M. Ralph and W. P. Norwood. 1989. Toxicity Test Procedres for *Hyalella azteca* and chronic toxicity of cadmium and pentachlorophenol to *H. azteca, Gammarus fasciatus* and *Daphnia magna*. Arch. Environ. Contam. Toxicol. 18: 189-197.

Brownlee, B.G., G.A. MacInnis, B.J. Dutka, W. Xu, W.L. Lockhart and D.A. Metner. 1993. Polycyclic aromatic hydrocarbon analysis and ecotoxicological testing of Athabasca River water and sediment. Presented at the 20th Aquatic Toxicity Workshop, Quebec City, October 17-20, 1993.

Day, K. and T.B. Reynoldson. 1995. Ecotoxicology of depositional sediments in the upper Athabasca River. Report prepared for the Northern River Basins Study, Edmonton.

Hanes, E. C. and J. H. Ciborowski. 1992. Effects of Density and Food Limitation on Size Variation and Mortality of Larval *Hexagenia rigida* (Ephemeroptera: Ephemeridae). Can. J. Zool. 70: 1824-1832.

MacInnis, G.A., B.G. Brownlee, B.J. Dutka and W. Xu. 1992. Toxicity testing of Athabasca River water and sediment. Poster presented at the 19th Aquatic Toxicity Workshop, Edmonton, October 4-7, 1992.

MacInnis, G.A., P.M. Nardini, B.G. Brownlee, B.J. Dutka and K.K. Kwan. 1994. Toxicity testing of suspended sediments from the Athabasca River. Presented at the 21st Aquatic Toxicity Workshop, Sarnia, October 2-5, 1994.